Feeding: Metazoan Predators
What do Metazoans Eat?

- **Other metazoans (carnivores)**
  - e.g., chaetognaths eat copepods & copepods eat smaller crustaceans

- **phytoplankton (herbivores)**
  - esp. larger ones like diatoms & dinoflagellates

- **jellyfish eat a wide range of prey from phytoplankton to fish**
  - salps/larvaceans are filter feeders
  - medusoid jellys are carnivores
Fish Larvae (Ichthyoplankton)

• Raptorial feeding mode, usually
  – exception: Clupeid fish, like herring and sardines, and anchovies, when they filter feed. Diet includes larger phytoplankton and small crustaceans.

• Larval fish (~1-3 mm+) important consumers of plankton

• Meroplankton (when adult, not considered plankton anymore)
Metazoan predators most common in the plankton -- Crustaceans & Chaetognaths

CRUSTACEANS - hard-bodied (chitinous exoskeleton) with specialized, segmented feeding, swimming, and sensory appendages. Some with functional, image-forming eyes. Responsive to mechanical, chemical, and light cues. Daily vertical migrations in many (larger) forms.

COPEPODS - "oar-foot", most numerous multicellular animals ("insects of the sea") and probably best studied zooplankton in the oceans. Many species benthic or parasitic. Most are less than 3 mm, the largest free-living form is about 16 mm. Suspension feeding via water currents generated by mouth parts, particles strained by appendages (2nd maxillae) with fine setae. Rapheal feeding by forms with larger, less setose maxillae and maxillipeds for grasping and manipulating prey. Most pelagic forms omnivorous.

EUPHAUSIDS - stalked compound eyes, shrimp-like body. Omnivorous, some suspension feed on larger phytoplankton such as diatom chains. Highly motile "micronekton", some larger forms exhibit schooling behavior. Euphausia superba ("krill") occurs in immense populations in Antarctic waters where it is the main food source for baleen whales, penguins, etc.

AMPHIPODS - sessile compound eyes, legs usually modified for grasping. Most benthic, most open ocean forms appear to live on, or in association with, gelatinous zooplankton, e.g., salps and jelly fish. Most forms predators.

The crustaceans also include shrimp, crabs, lobster and many other forms that are planktonic only as larvae (meroplanktonic, as opposed to holoplanktonic - planktonic for entire life).

CHAETOGNATHS - "arrow worms" with elongated body separated into head, trunk, and tail. Exclusively marine. Head with paired eyes and prehensile, chitinous jaws with hooks. Ambush predator, responds to mechanical cues, swallows prey (copepods, fish larvae, other chaetognaths) whole. Hermaphroditic; testes in tail, ovaries in trunk.
Crustacea (metazoans)

- Most common (numbers and biomass): copepods
- Well-studied: easily caught with nets and seen with low power microscopes or naked eye
- Specialized feeding appendages
  - Filter or Suspension feeders (usu. herbivores)
  - Raptorial feeders (usu. carnivores)
Crustacean feeding appendages

filter feeder: crushing mandible, fine hairs on appendages

predator: slicing mandible, no hairs on appendages
Movies & Animations of raptorial & filter feeding copepods

http://jaffeweb.ucsd.edu/vcpanimations

&

http://www.planktonsafari.net/
Why some don’t feed on small organisms

Herbivorous copepod, *Acartia clausi*

Fig. 1. Manilla of adult female *Acartia clausi* (drawn after a photograph of a mounted limb) showing the position of the setules on the setae and the way the measurements were made for surface calculations. \( w \) = width of the small (\( w_s \)) and large (\( w_l \)) meshed region; \( m_l \) = mean length of the setae of the small (\( m_{ls} \)) and large (\( m_{ls} \)) meshed region.

Nival & Nival 1976

Fig. 3. Spectra of filtration efficiency (computed from the measurements of setae) for each developmental stage of *Acartia clausi*. Each line represents the spectrum of one animal; curves were interrupted as soon as 100% efficiency was reached.
Crustaceans that CAN capture small prey
e.g., euphausiids feeding appendages

Fig. 7.2  Thoracic legs of particle-feeding euphausiids bear long anteriorly directed setae forming a filter basket (closed in a). This fills from the front, beneath the antennae, when the legs are opened (b; flow is shown by the dye stream moving from a pipette tip at the right). During opening the filter surface is covered by the exopods (outer legs) to keep water from moving in through the screen. (After Hamner 1988.)
Gelatinous Zooplankton
Example: Appendicularians

ex. *Oikopleura*

Potentially important as grazers of picoplankton
e.g., episodically responsible for removing 50-60% of standing stock daily in K. Bay (Scheinberg et al. 2005 MEPS, 294, 201-212)
Selective Feeding

Most important factors contributing to selective feeding:

- Prey Size
- Prey Motility
- Prey surface chemistry
- Predator chemosensory behavior
Prey: Predator Size Ratios

All organisms feed selectively, the optimal range of prey being determined by:

- Sensory mechanisms & thresholds for detecting prey
- Physical constraints on contact (encounter) frequency
- Minimum size that can be effectively captured/handled
- Maximum size that can be effectively captured/handled

Typical: \[
\frac{\text{Predator length}}{\text{Optimal prey length}} \approx 10
\]
Microzooplankton optimum prey selection: Is it 10:1?

Fig. 2. Optimum prey size vs. predator size, both expressed as equivalent spherical diameter (ESD), data from Table 1. Lines represent average predator:prey size ratios for different groups of organisms (cf. Table 2).

Hansen et al. 1994

Fig. 3. Provisional size selectivity spectra for different pelagic predators based on information in Tables 1 and 2.
Metazoan Predators
Raptors above the 1:10 line

ambush predators/raptors
raptorial feeders
Filter feeders below 1:10 line

Filter feeders

Predator-prey size relationships

PREY SIZE

PREDATOR SIZE
Copepod Size Selection

*Calanus pacificus*: higher clearance rates on larger prey items

Frost 1972

Fig. 5. Relationship between volume swept clear, $F$, for adult females of *Calanus* and mean cell volume of diatoms used as food. Values of $F$ are means based on rates measured at cell densities below the critical concentration for each species of diatom (Figs. 2 and 4). $F$ is predicted by the least-squares regression line $F = 2.61(\log V) - 4.84$, where $V$ is the cell volume ($\mu^3$) of the centric diatom used as food. The correlation coefficient between $\log V$ and $F$ is 0.79 ($N = 95$).

http://www.ecohabpnw.org
Dinoflagellate feeding on algae

Microzooplankton Size Selection

Weisse & Kirchhoff 1997

Fig. 8. Size-selective grazing of *Peridinium beroide* (dark shaded area) versus the initial algal size distribution (light shaded area) measured by EPCS in the first experiment. The y-axis denotes count rate, i.e., number of particles per each of the 1024 channels of the equivalent spherical diameter (ESD, x-axis); the latter is a measure of cell size. The dark area thus indicates the size range where feeding was effective and the number of algae in each channel that have been grazed during the experiment. Cursors mark the abundance peak of *Rhodomonas minuta* (left) and *Cryptomonas* sp. (right), respectively. The corresponding ESD are given in the top right corner (CL: cursor left, R. minuta, C.R: cursor right, Cryptomonas sp.)
Selection based on Prey Size

Monger & Landry 1992
Motility of Prey

Uptake of fluorescently-labelled, living and heat-killed cultures of a highly motile marine bacteria (Kaneohe Bay isolate) by the flagellate HNAN.

Monger & Landry 1992
Prey motility a factor for other predators?

**Cruising (swimming) predators:**
Swimming prey will increase encounter rates

**Ambush (sit-and-wait) predators:**
Predators that detect prey motion (vibrations) will clearly detect more motile prey
Copepod diets vs. Ambient food availability

(a) Central California, Aug. 2, 1987 – Diatom bloom at front
- Microplankton
- Calanus pacificus

(b) Irish Sea, May 3, 1989
- Microplankton
- Calanus helgolandicus

(c) Irish Sea, May 2, 1989
- Microplankton
- Temora longicornis

(d) NE Gulf of Mexico, Mar. 21, 1992
- Microplankton
- Undinula vulgaris

(e) Los Angeles Harbor, Nov. 1986 to Oct. 1987 (mean of 10 expts)
- Microplankton
- Acartia tonsa

(f) Los Angeles Harbor, Apr. 1987 – Dinoflagellate bloom
- Microplankton
- Acartia tonsa

(g) Los Angeles Harbor, Feb. 1987 – Low production period
- Microplankton
- Acartia tonsa

(h) NE Gulf of Mexico, Mar. 21, 1992
- Microplankton
- Centropages furcatus

Kleppel 1993
Some predators switch between one behavior and another to optimize energy intake.

**Centropages**: ciliates preferred as prey if over 5% of the mixture.

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**Fig. 3.** *Centropages hamatus*. Feeding of males (m; filled) and females (f; open) on ciliates when offered a mixture of *Rimicarchesium conicum* and *Thalassiosira weissflogii* (see Section 2 for details). Error bars indicate mean ± standard error.

Saage et al. 2009

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**Acartia tonsa** feeding on diatoms vs. ciliates.

**Fig. 4.** *Acartia tonsa*. Clearance rate of diatoms by *A. tonsa* as a function of feeding bout activity: (●) mixture of diatom *Thalassiosira weissflogii* and ciliate *Strombidium sulcatum*; (○) *T. weissflogii* only. Feeding bout activity and clearance were measured in separate experiments conducted simultaneously. The regression is statistically significant (*n* = 6, *r*² = 0.84, p < 5%). Error bars show ± SD.

Kiorboe et al. 1996
Copepod Selective Feeding: toxic and non-toxic dinoflagellate

When offered both prey types, fed more on non-toxic species

Prey rejection frequencies same between mono and mixed diets: suggests remote sensing (chemosensis) of cells
Chemosensory Behavior in Protists?

- Closed circles: FLB
- Open circles: latex beads

Fenchel 1980 & Sherr & Sherr 1987

- Closed circles: FLB
- Open circles: microspheres
- Ciliate w/fixed filter apparatus

Sherr et al. 1987

- Ciliate w/membranelle filter
Pallium Feeding

- Preferred diatoms over dinoflagellate prey
- Appeared to respond to chemosensory cues
- Had greater capture success with non-motile prey

- Higher growth rate on diatoms (0.7 d\(^{-1}\)) vs. dinoflagellates (0.4 d\(^{-1}\))

Table 2. Observed feeding interactions between *Protoperaudium pellucidum* and 4 potential food types: *Ditylum brightwellii*, *Thalassiosira sp. 1*, *Gonyaulax polyedra* and *Prorocentrum micans*. If *P. pellucidum* formed a pallium around its food cell, it was scored as a successful capture. If the cell was lost after the tow thread was attached, it was scored as an escape. If *P. pellucidum* circled the cell in a stereotypic feeding behavior, but failed to attach a tow thread, it was scored as a lost contact. \(n = \) no. of observations.
Selective Feeding Summary

- **Prey Size:**
  - each predator has an optimum size range of prey

- **Prey Motility:**
  - motile prey tend to be found and consumed at a higher rate

- **Prey surface chemistry:**
  - certain chemical properties of the prey are attractive to predators (and vice versa)

- **Predator chemosensory behavior:**
  - predators use chemical cues to find and choose amongst prey